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DEVELOPMENT AND TESTING OF PEDAL OPERATED THRESHER FOR FINGER MILLET

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ABSTRACT

This paper deals with the development and testing of a pedal operated finger millet thresher. The prevalent millet threshing method like beating with sticks, rubbing and trampling finger-heads under bullock's feet or men feet are tedious and labour and time consuming. Pedaling is the most efficient way of utilizing power from human muscles. Keeping this thing in mind pedal operated thresher for minor millets with spike-tooth type threshing cylinder was developed and tested. The physical properties of finger millet grain such as moisture content, bulk density, straw grain ratio, size, and angle of repose was studied. A finger millet thresher of feeding capacity 43.37 kg/h was designed on the basis of these physical properties. The thresher was tested with a view to increasing the threshing efficiency and reducing the cost of threshing in comparison with traditional method of threshing of finger millet. It was observed that the maximum threshing efficiency of 68% can be achieved by threshing the finger millet crop at 11% mc at the peripheral speed of 11.18m/s (850 rev/min), when the concave clearance is 7mm. The thresher was tested at three different speeds for its performance in terms of threshing and cleaning efficiency, visible damage, germination percentage, and sieve losses.

KEYWORDS: Pedal Operated Millet Thresher, Traditional Method of Threshing, Human Energy Expenditure

INTRODUCTION

India is the largest producer of many kinds of millets. Finger millet is also known by the name *Ragi*. It is an important small millet food and fodder crop which is extensively cultivated in Asian countries like India, Malaysia, China and Nepal. In India it is cultivated over an area of 2.65 million hectare. Finger millet has total production of about 2.9 million tonnes. Finger millet has outstanding properties as a subsistence food crop. Finger millet is harvested either manually by using sickle if it is intercropped with legumes or by reaper windrower if it is grown as single crop. It is estimated that harvesting and threshing of crops consume about one third of the total effort requirement of the production system. (Sreenatha A., 2010)

Millets are important food for sustaining tribal population in Bastar region of India. The important small cereals among tribes of Bastar region after rice are kodo millet (*Paspalum scrobiculatum* L.) and finger millet (*Eleusine coracana* L. Craertn) (Verma and Mishra, 2010). Chhattisgarh facing problems of power storage due to rapid industrialization, like non availability of power in interior areas and large scale unemployment of semi-skilled worker. In the recent years, a human-powered process machine has been developed for brick making , wood turning, finger type torsionally flexible clutch for a low capacity manually energized chemical unit and battery charging (Modak and Modhe, 1998).

The present design of threshers available in the market are mostly for threshing of cereal and legume crops rather than minor millets like finger millet (Ragi) and kodo millet, hence only conventional method is used by the farmers. Threshing process of the millet is a major constraint in this regard. The traditional method for threshing of kodo millet and finger millet is generally done by hand. Bunches of panicles are beaten against hard elements (e.g. a wooden bar log, bamboo table or stone). In many areas, the crop is threshed by being trodden underfoot by humans or animals (Naveen et al., 2013). This method often results in some losses due to the grain being broken or buried in the earth. Often this local method of processing the crop leads to low quality product due to the presence of impurities like stones, dust and chaff.

The socio-economic conditions of farmers living in villages of developing countries including India, human muscles power can be good alternative to fulfill the energy requirements for performing many activities like threshing. Pedaling is the most efficient way of utilizing power from human muscles. The power level that can be produced by an average healthy athlete is 75 W maximum (Modak and Bapat, 1987). A person can generate more or same amount of power for longer time if they pedal at certain rate. A simple rule is that most people engaged in delivering power continuously for an hour or will be more efficient when pedaling rate is in the range of 50-70 rpm (Tiwari et al., 2011). Keeping these things in mind the study was planned to develop a pedal operated millet thresher and tested the developed unit for different crop and machine parameters.

MATERIALS AND METHODS

The machine basically consists of four major components: Drive unit, frame assembly, feeding Mechanism, threshing mechanism (consisting of threshing cylinder, concave and cylinder casing), separation and cleaning mechanism. The machine consists of a chain drive and belt drive that rotates the threshing cylinder and blower shafts. The machine can be used by common people, save time otherwise spent in traditional method.

Construction and Working of Pedal Operated Finger Millet Thresher

Drive Unit

The seat is adjustable in height to fix the height according the operators posture and comfort. Pedal were transmitted human power to all the units of threshers by using chain drive and v-belt drive as power transmission device. The pedals, in turn, are fixed to a chain ring (sprocket) with teeth that engages the bicycle’s continuous chain. The chain then transmits the pedaling action to a cog on the hub of the front wheel causing the front sprocket to rotate and then drive the shaft on which pulley is mounted. A sprocket of 250 mm diameter (60 teeth) is fitted on pedal operated shaft. The pedal power is transmitted to the main pulley of 300 mm diameter fitted with smaller sprocket having diameter of 70 mm (18 teeth). The main pulley transmitted power to the threshing unit (50 mm diameter pulley) by a V-belt. The threshing unit sep up pulley (100 mm) transmit power to the blower pulley (140 mm). Step-up pulley (130 mm) transmits power to the sieve shaker pulley (225 mm).

Frame Assembly

The frame was made of mild steel angle, which gives sufficient strength to the thresher. The frame was fabricated from 35 x 75 x 2 mm channel section. Four iron angle of 35 x 35 x 5 mm size were welded vertically on it to support the side plates. Four angles were bolted on the support in bearing and roller shaft. The provision was made on the frame for fixing. The main frame was 2500 mm long, 1130 mm wide and 1140 mm in height. Four wheels were provided for easy transportation of thresher.

Feeding Mechanism

The feeding chute was fabricated by using mild steel sheet. The feeding hopper is welded to the top cover of the threshing unit, which is hinged on mainframe of the thresher it can be lifted up for visual observations and clearing of the space between roller and belts. The dimensions of the feed hopper are 320 x 220 x 340 mm (L x W x H) with thickness of 2 mm.

Threshing Unit

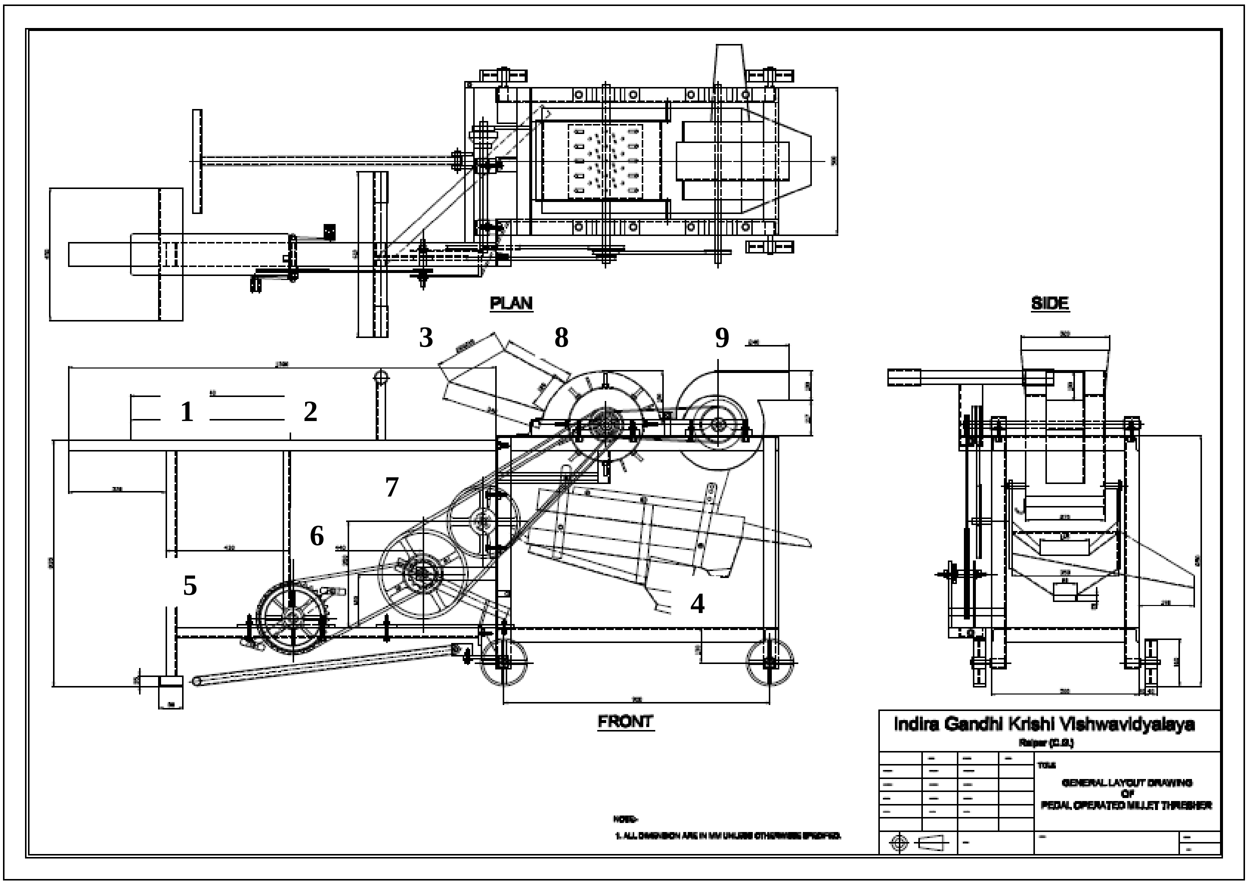
The threshing unit of the pedal operated finger millet thresher consists of driving pulley is fitted on chain and sprockets belts are mounted for threshing the ear-head samples. The millet thresher fitted with a closed type spiked tooth threshing cylinder of 250 mm diameter. Round shaped 10 mm diameter spikes (36 Nos) are bolted in 4-paired rows and rectangular plate of 55 x 25 x 3 mm was welded (16 Nos), in staggered manner on the cylinder. Spike length can be adjusted to change the cylinder concave clearance. The cylinder top cover is semicircular in shape and is made of mild steel sheet. Angle iron pieces (25 x 25 x 3 mm size) are welded on the inner side of cover parallel to axis to act as rubbing base for threshing of the crop. The square bars are welded to two semicircular mild steel side plates at 7 mm or 9 mm gap. The concave adjusting the length of spikes the width and length is 250 mm and 450 mm respectively.

Separation and Cleaning Mechanism

An aspiratory blower is provided on a separate shaft behind the threshing cylinder. The blower diameter was 290 mm. The blower fan consisted of four blades of the size of 140 x 115 mm made of 2 mm thick mild steel plates. Sieve shaker consists of three sieves with separate outlet and is suspended below the cylinder concave assembly on the main frame, through hangers. The top sieve separates the heavier pieces of straw from grain and can be changed as per crop. The grains; passes through the top sieve to middle sieve, which separates the grain from fine material (dust, grass, seeds, etc.) and clean grain flows out from middle sieve outlet. Fine material passing through the middle sieve is collected at the bottom outlet.

Working Principle of Pedal Operated Finger Millet Thresher

The rotary motion of foot pedal is transmitted through crank, chain –sprockets and belt –pulleys to the threshing unit (Figure 1). Each rider accelerates the threshing cylinder to the speed of 800rpm in 1 minute. The drive unit mainly concerns with transmission of human power to threshing unit. The speed ratio of pedal to the threshing cylinder is 1:20. This transmission of human power to threshing unit is accomplished in two stages. In first stage the operator uses his feet and legs to rotate pedal around the crank axel. The pedals in turn are fixed to chain ring (sprocket) with the teeth that engages continuous chain. The chain then transmits the pedaling action to cog on the front wheel causing the front sprocket to rotate and then drive shaft on which pulley is mounted. In second stage this power from shaft and pulley is transmitted to threshing unit through belt drive. The ears of millets are fed through feed inlet to the threshing unit. The rubbing and impact action caused by the belt help in separation of grain from ears and breakage of straw. The blower creates the air draft, so that light material is sucked up the air passage. The seed drops at the discharge end. The light material on leaving the air passage is thrown against the wall of chamber due to centrifugal force. The flow of the air from the blower is controlled by a sliding gate on top of the blower chamber, which helps to improve the cleaning. The speed is adjusted by changing the drive pulley on the pedal.



(1.Saddle, 2.Handle, 3. Fedding chute, 4. Sieve mechanism, 5. Chain wheel, 6. Main pulley, 7. Sieve shaker pulley, 8. Threshing unit, 9. Blower unit)

Figure 1: Design Layout of Pedal Operated Minor Millet Thresher

Figure 2: Testing of Pedal Operated Minor Millet Thresher

Testing Procedure

The performance of pedal operated minor millet thresher was evaluated at workshop of FAE, IGKV Raipur. The performance evaluation of the thresher was carried out with respect to threshing and cleaning efficiency, total grain loss (including blown grain, broken grain and grain impurities) and germination percentage for finger millet crop at different pedaling speeds 35, 45 and 55 rpm. The finger-head of finger millet crop (VR-708) were taken for testing and evaluation of pedal operated millet thresher. Before conducting the test, crop parameters related to crop length, ear head length, bundle diameter, stem diameter at cutting portion, bundle weight, grain-straw ratio, straw and grain moisture were measured and about 50 bundles were kept near the machine which were fed in the pedal operated millet thresher continuously one after another.

RESULTS AND DISCUSSIONS

Effect of Cylinder Speed on Threshing Efficiency and Cleaning Efficiency

The threshing efficiency increased with increase in cylinder speed, because of higher speed the energy imparted to the ear head increased due to increase in impact force which led to reduction in unthreshed grains. The Figure 3 shows that the minimum threshing efficiency of 66.92 per cent was observed at lower cylinder peripheral speed of 8.5 m/s.

The cleaning efficiency was minimum (88.77%) at lower cylinder peripheral speed of 8.5 m/s and maximum (89.52%) at higher cylinder peripheral speed of 11.12 m/s. The cleaning efficiency was more at higher cylinder speed due to higher reduction in size of separated straw.

Effect of Cylinder Speed on Grain Losses

It is seen from the Figure 4 that the broken grain percentage increased with increase in cylinder speed. The broken grain was found 4.21, 5.33 and 5.87 per cent at cylinder peripheral speed 8.5, 11.12, and 13.08 m/s respectively. At higher blower speed air velocity increased which in turns increased the percentage of blown grain. It is clear from the figure that percentage of blown grain increased with increase in cylinder speed but percentage of unthreshed grain decreased with increase in cylinder speed.

Effect of Cylinder Speed on Germination Percentage

The relationship of the effect of cylinder speed on germination percent is shown in Figure 5. It is seen from the figure that germination percentage decreased with the increase in cylinder speed. The variation of germination was found to be between 85 to 88.33 percent. The minimum germination (85%) was found at higher cylinder peripheral speed of 13.08 m/s. The germination percentage was maximum (88.33 %) at lower cylinder peripheral speed 8.5 m/s. The reason for less germination percentage at higher cylinder speed is that the grain is subjected to more impact and rubbing forces which in turn cause both external and internal injuries to the grain.

3.4. Effect of Cylinder Speed on Feed Rate and Output Capacity

It is clear from the Figure 6 that as the cylinder speed increased the feed rate also increased. The maximum feed rate (43.37 kg/h) was observed at higher cylinder peripheral speed of 13.08 m/s. The feed rate was minimum (39.13 kg/h) at lower cylinder speed of 8.50 m/s. These results are in conformity with the findings of Sharma and Devnani (1980). They observed that the feed rate increased with the increase in cylinder tip speed at all concave clearances.

The output capacity was maximum (7.17 kg/h) at higher cylinder peripheral speed of 13.08 m/s. The minimum output capacity (6.39 kg/h) was observed at lower cylinder peripheral speed of 8.5 m/s. These results are in conformity with the findings of Sharma and Devnani (1980) and Dash and Das (1989). They reported that the output capacity was minimum at lower cylinder speed.

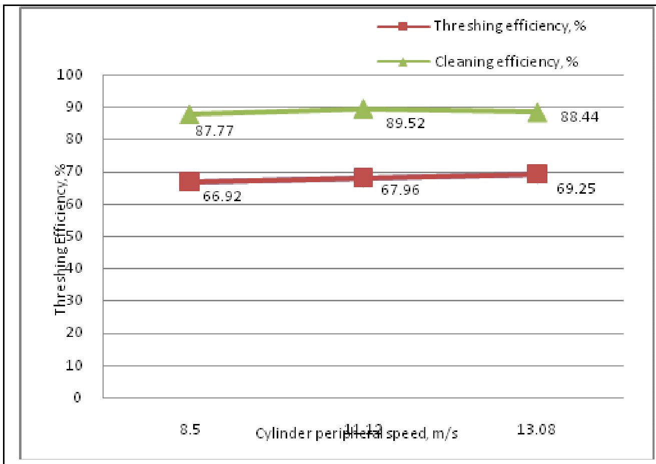


Figure 3: Effect of Cylinder Speed on Threshing and Cleaning Efficiency

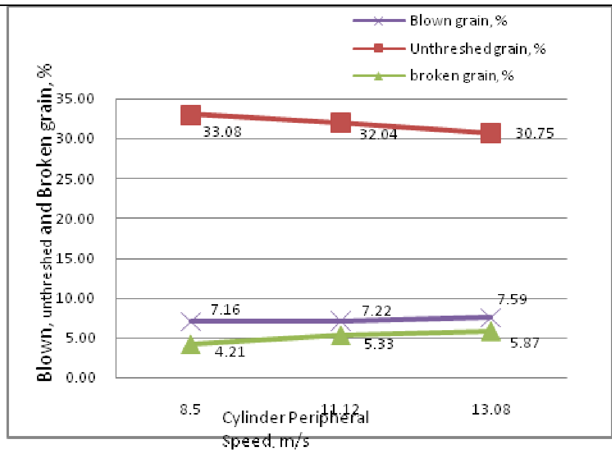


Figure 4: Effect of Cylinder Peripheral Speed on blown, Unthreshed and Broken Grain

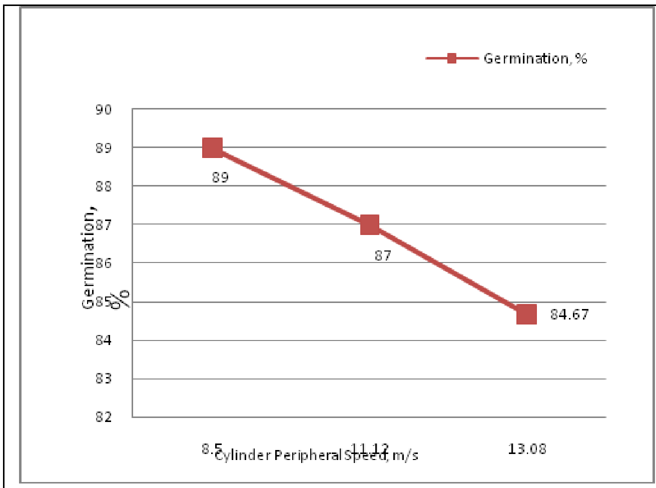


Figure 5: Effect of cylinder Speed on Germination Percentage

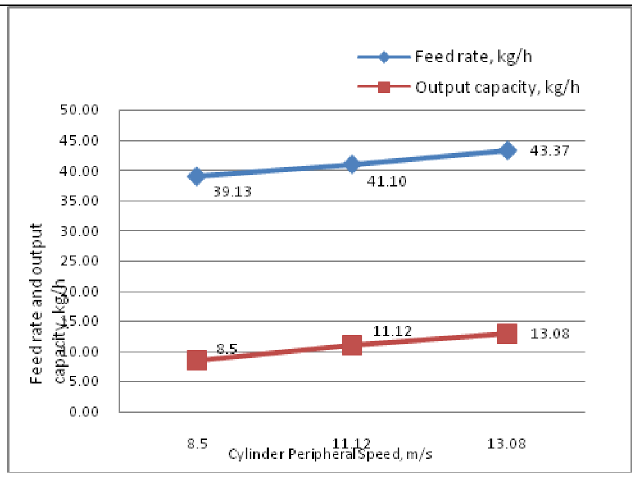


Figure 6: Effect of Cylinder Speed on Feed rate and Output Capacity

Overall Performance of Pedal Operated Finger Millet Thresher

The performance of thresher was evaluated at feeding rate of 39.13 to 43.37 kg/h whereas the output capacity was found to vary from 6.39 to 7.17 kg/h for finger millet crop. The test results are given in Appendix-2. The performance of pedal operated millet thresher was evaluated at three different pedaling speeds 35, 45 and 55 rpm at cylinder peripheral speed of cylinder was 8.50, 11.08 and 13.08 m/s respectively. The speed ratio of pedal to the threshing cylinder is 1:20. The unthreshed grain were found 33.08, 32.04 and 30.75 %, broken grain were found 4.20, 5.33 and 5.87% and of blown grain were found 7.16, 7.22 and 7.59 % at pedaling speeds 35, 45 and 55 rpm respectively. The threshing efficiency was found 66.92, 67.96 and 69.25 % and cleaning efficiency was 87.77, 89.52 and 88.44 % at pedaling speeds 35, 45 and 55

rpm respectively.

CONCLUSIONS

From above discussion it can be concluded as

- Human power is easy to use and no need of special training, Low initial and maintenance cost., Self-dependent source of energy So it is the best alternative source of energy.
- The cleaning and threshing efficiencies were observed to increase when the cylinder peripheral speed was increased. The threshing efficiencies and cleaning efficiencies ranged between 66 to 69 per cent and 87 to 89 per cent respectively.
- All the grain losses including broken grain loss, blown grain loss and total grain loss were observed to increase on increasing the cylinder peripheral speed. The minimum grain loss (44 %) and maximum grain loss (44.59%) was observed at cylinder peripheral speed of 13.08 and 11.12 m/s respectively.
- Output capacity was increased with an increase in cylinder peripheral speed.
- Feed rate was found to increase with increase in cylinder peripheral speed. The feed rate was ranged between 39.13 to 43.37 kg/h for finger millet crops.
- Germination percentage was found to decrease with increase in peripheral speed of threshing cylinder. The Germination percentage ranged from 85 to 88.33 per cent.
- The best pedaling speed in order to obtain higher output capacity, higher cleaning and threshing efficiencies, minimum grain losses and optimum germination percentage at 10.59 per cent grain moisture content was 45 rpm (cylinder peripheral speed of 11.12 m/s). The thresher is, therefore, recommended to operate at this pedaling speed for its best performance.
- Threshing with pedal operated millet thresher was the best method for threshing finger millet crops than the traditional method.

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APPENDICES

Testing of Pedal Operated Finger Millet Thresher at different Cylinder Speed

Appendix 1: Crop Factors

Sr. No.	Particulars	Pedaling speed (rpm)											
		35				45				55			
		Cylinder speed, rpm (m/s)											
		650 (8.50)				850 (11.18)				1000 (13.08)			
		T-1	T-2	T-3	Avg.	T-1	T-2	T-3	Avg.	T-1	T-2	T-3	Avg.
1	Length of crop, cm	53.5	56.2	52.2	**53.97**	48.5	55.7	53.1	**52.43**	52.1	53.7	52.2	**52.67**
2	Length of panicle, cm	13.2	12.56	12.87	**12.88**	12.56	13.1	13.15	**12.94**	12.35	12.76	12.98	**12.70**
3	Weight of one bundle, kg	5	5	5	**5.00**	5	5	5	**5.00**	5	5	5	**5.00**
4	No. of bundles, kg	7.76	7.94	7.78	**7.83**	7.88	8.36	8.42	**8.22**	8.5	8.92	8.6	**8.67**
5	Total wt. of bundles, kg	38.8	39.7	38.9	**39.13**	39.4	41.8	42.1	**41.10**	42.5	44.6	43	**43.37**
6	Grain-straw ratio												
(a)	Total crop weight, kg	38.8	39.7	38.9	**39.13**	39.4	41.8	42.1	**41.10**	42.5	44.6	43	**43.37**
(b)	Grain weight, kg	9.89	10.32	10.09	**10.10**	10.36	11.05	11.23	**10.88**	11.18	11.7	11.27	**11.38**
(c)	Straw weight, kg	28.91	29.38	28.81	**29.03**	29.04	30.75	30.87	**30.22**	31.32	32.9	31.73	**31.98**
(d)	Grain-straw ratio	0.342	0.351	0.350	**0.348**	0.357	0.359	0.364	**0.360**	0.357	0.356	0.358	**0.357**
7	Grain moisture content, (% d.b.)	10.5	10.68	10.59	**10.59**	10.5	10.68	10.59	**10.59**	10.5	10.68	10.59	**10.59**
8	Straw moisture content, (% d.b.)	12.8	12.74	12.81	**12.78**	12.8	12.74	12.81	**12.78**	12.8	12.74	12.81	**12.78**

Appendix-2: Performance Data

Sr. No.	Parti culars	Pedaling speed (rpm)											
		35				45				55			
		Cylinder speed, rpm (m/s)											
		650 (8.50)				850 (11.18)				1000 (13.08)			
		T-1	T-2	T-3	Avg.	T-1	T-2	T-3	Avg.	T-1	T-2	T-3	Avg.
1	Feed rate, kg/h	38.80	39.70	38.90	**39.13**	39.40	41.80	42.10	**41.10**	42.50	44.60	43.00	**43.37**
2	Threshing efficiency, %	66.13	67.44	67.20	**66.92**	68.24	67.78	67.85	**67.96**	69.41	69.40	68.92	**69.25**
3	Cleaning efficiency, %	87.86	86.67	88.77	**87.77**	88.13	90.16	90.28	**89.52**	87.99	88.63	88.71	**88.44**
4	Seed Recovery, %	93.95	94.36	94.83	**94.38**	94.82	94.29	94.84	**94.65**	95.13	94.91	95.44	**95.16**
5	Broken grain, %	3.74	4.42	4.46	**4.20**	5.50	4.98	5.52	**5.33**	5.72	6.15	5.74	**5.87**
6	Blown grain, %	6.77	7.56	7.14	**7.16**	8.30	5.61	7.75	**7.22**	7.33	7.95	7.50	**7.59**
7	Unthreshed grain, %	33.87	32.56	32.80	**33.08**	31.76	32.22	32.15	**32.04**	30.59	30.60	31.08	**30.75**
8	Total grain loss, %	44.39	44.53	44.40	**44.44**	45.56	42.81	45.41	**44.59**	43.65	44.70	44.31	**44.22**
9	Germination, %	90	88	89	**89**	86	88	87	**87**	86	83	85	**84.67**
10	Output capacity, kg/h	6.26	6.60	6.32	**6.39**	6.40	7.01	6.79	**6.73**	7.16	7.30	7.06	**7.17**